

MICRO CHANNEL UNIT

BACKGROUND OF THE INVENTION

5 This application claims the priority of Korean Patent Application No. 2002-50128, filed on August 23, 2002, the disclosure of which is incorporated herein in its entirety by reference.

1. Field of the Invention

10 The present invention relates to a micro-scale channel unit, and more particularly, to a micro channel unit having the shape of a connecting channel portion in order to reduce the pressure loss at a connection portion between adjacent straight channel portions in the channel unit.

2. Description of the Related Art

15 In recent days, micro-electromechanical systems (MEMS) are frequently used in the fields of life science, genetic engineering, disease diagnosis and new drug development for the detection and analysis of DNA or proteins, the measurement of micro volumes of vital metabolites and reactants, etc. As such, research on micro fluidic MEMS is a key factor to further miniaturize and improve the performance of
20 existing analysis equipment.

 For example, biochips used for new drug development and blood analysis include micro-scale channel units through which a fluid specimen to be analyzed passes. In this respect, it is desirable to make a channel in a micro-scale channel unit long enough to improve the performance of material extraction, chemical
25 reactions, and mixing of substances.

 However, micro channel units cannot accommodate only straight channels due to the miniature size of the biochip. To solve this problem, as shown in FIG. 8, connecting channel portions 120 and 130 curved at 90 and 180 degrees are used to connect adjacent straight channel portions 110, thereby providing long flow
30 passages in the limited space of a micro channel unit 100. The widths of the connecting channel portions 120 and 130 are usually the same as those of the straight channel portions 110.

 However, compared with a case where fluid passes through the straight channel portions 110, the fluid suffers much more pressure loss when it passes

through the curved connecting channel portions 120 and 130. Also, the longer the channel becomes, the more pressure loss occurs. Therefore, more power to drive the fluid flow and so a relatively larger pump are required, which is undesirable for a miniaturized biochip.

5 Thus, it is of great importance to adequately design the connecting parts of the channel unit to reduce the fluid pressure loss.

SUMMARY OF THE INVENTION

10 The present invention provides a micro channel unit constructed to reduce a fluid pressure loss in connecting channel portions between adjacent straight channel portions.

15 In accordance with an aspect of the present invention, there is provided a micro channel unit including a micro channel with a width of micrometer dimensions, through which liquid flows. The micro channel includes a plurality of straight channel portions extending in a straight line pattern and the connecting channel portions that connect adjacent straight channel portions. Here, the connecting channel portions are wider than the straight channel portions.

20 In the micro channel according to the present invention, each connecting channel portion may become progressively wider from one of two adjacent straight channel portions connected by the connecting channel portion, toward the other straight channel portion, and is widest in a middle portion. Also, the connecting channel portion is smoothly curved.

BRIEF DESCRIPTION OF THE DRAWINGS

25 The above and other features and advantages of the present invention will become more apparent by describing in detail exemplary embodiments thereof with reference to the attached drawings in which:

FIG. 1 is a schematic perspective view of a micro channel unit according to an embodiment of the present invention;

30 FIG. 2 is a cross-section of the micro channel unit taken along the line II-II in FIG. 1;

FIG. 3 is a graph illustrating an optimal shape of the connecting channel portion (curved at 90 degrees) shown in FIG. 1;

FIG. 4 is a graph illustrating an optimal shape of the connecting channel

portion (curved at 180 degrees) shown in FIG. 1;

FIG. 5 is a schematic diagram showing a fully developed fluid flow in a connecting channel portion shown in FIG. 1;

FIG. 6A is a graph showing the distributions of skin friction on the wall within a micro channel in the micro channel unit of FIG. 1, the connecting channel portion being curved at 90 degrees;

FIG. 6B is a graph showing the distributions of skin friction on the wall within a micro channel in the micro channel unit of FIG. 1, the connecting channel portion being curved at 180 degrees;

FIG. 7A is a graph showing the distribution of pressure on the wall within a micro channel in the micro channel unit of FIG. 1, the connecting channel portion being curved at 90 degrees;

FIG. 7B is a graph showing the distribution of pressure on the wall within a micro channel in the micro channel unit of FIG. 1, the connecting channel portion being curved at 180 degrees; and

FIG. 8 is a schematic perspective view of a conventional micro channel unit.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIGS. 1 and 2, micro channels for liquid flow with the widths of micrometer-dimension are formed in a micro channel unit 1. The micro channel unit 1 includes a plurality of straight channel portions 10 extending in a straight line pattern, connecting channel portions 20 and 30 that connect pair of adjacent straight channel portions 10, the channel inlet 2, and the channel outlet 3.

The micro channel unit 1 may be formed in a substrate made of silicon or glass using dry etching and laser cutting methods. These methods are not only well known in the art but also not directly related to this invention, so a detailed description thereof will be omitted.

Meanwhile, the micro channel unit 1 of the present invention is different from the conventional micro channel unit 100 described and shown with reference to FIG. 8 in the structure of the connecting channel portions 20 and 30. That is, while in the case of the conventional channel unit 100 shown in FIG. 8, the widths of the connecting channel portions 120 and 130 are the same as those of the straight channel portions 110 connected by the connecting channel portions 120 and 130, the widths of the connecting channel portions 20 and 30 are larger than those of the

straight channel portions 10 in the case of the micro channel unit 1 according to this invention as shown in FIGS. 1 through 4.

In particular, in the micro channel unit 1, the connecting channel portion 20 or 30 becomes progressively wider from one of two adjacent straight channel portions 10 connected by the connecting channel portion 20 or 30, toward the other straight channel portion 10, and is widest in a middle portion.

Specifically, referring to FIG. 2, where reference character W denotes the width of the channel, in the case of the connecting channel portion 20 curved at 90 degrees, width W_2 at a portion adjacent to one of the two adjacent straight channel portions 10 is larger than width W_1 of the straight channel portion 10. Width W_3 in the middle of the connecting channel portion 20 is the largest among widths W_1 , W_2 , W_3 , and W_4 , and Width W_4 at a portion adjacent to the other straight channel portion 10, which is smaller than W_3 , decreases to eventually be the same as the width W_1 of the other straight channel portion 10.

Similarly, in the case of the connecting channel portion 30 curved at 180 degrees, width W_5 at a portion adjacent to one of the two adjacent straight channel portions 10 is larger than the width of the straight channel portion 10. Width W_6 in the middle portion of the connecting channel portion 30 is the largest among widths W_5 , W_6 , and W_7 . Width W_7 at a position adjacent to the other straight channel portion 10, which is smaller than W_6 , decreases to eventually be the same as the width of the other straight channel portion 10.

The shape on either sidewall of the connection channel portion 20 or 30 is preferably curved so that friction force exerted on the wall is almost equal to zero. According to a well known optimal control theory, the curved shape on the sidewall of the connecting channel 20 or 30 can be optimized so that the frictional force between fluid flow in the connecting channel portion 20 or 30 and the wall of the connecting channel portion 20 or 30 becomes almost equal to zero. Thus, a pressure drop between both ends of the connecting channel portion 20 or 30 can be reduced as much as possible by optimizing the curved shape of the sidewall thereof.

To support this fact, referring to FIGS. 5-7, the state of the fluid flow is mainly dependent on the viscosity of the fluid. To cause the fluid to flow, power or a pressure difference that is large enough to overcome flow resistance due to the viscosity is needed. In FIG. 5, p , dp , τ , and dx denote pressure, pressure

difference, skin friction and streamwise distance, respectively. In case of fully developed flow of the fluid in the channel, the pressure difference equivalent to a sufficient amount of power to drive the fluid is proportional to the skin friction. That is, the relationship is given by the following equation:

$$-dp/dx = 2\tau /h$$

where $-dp/dx$ and h denote a pressure gradient in the streamwise direction and a channel width, respectively, and the negative sign (-) indicates a pressure drop in the streamwise direction.

If the widths of the connecting channel portions 20 and 30 are larger than the widths of the straight channel portions 10 as described above, the mean velocity of the flow decreases in the connecting channel portions 20 and 30 and the gradient of the velocity on the wall thereof decreases, thereby reducing the frictional force between the fluid and the wall. Thus, the pressure drop between both ends of the connecting channel portion 20 or 30 decreases so that it almost becomes equal to zero by reducing the skin friction τ on the wall to be nearly zero using the optimal control theory.

An example of an optimally shaped curved micro channel will be shown. In a biochip, blood or dilution of blood with water was used as a specimen fluid. The velocity (u) of the solution is normally 1-10 mm/s, the width (h) of a channel is about 100 μ m, the kinetic viscosity (ν) of the fluid is about $1 \times 10^{-6} \sim 4 \times 10^{-6}$. Here, Reynolds number (Re) defined as $Re=uh/\nu$ is about 0.1 - 1, which characterizes the flow in a micro channel.

FIGS. 6A and 6B are graphs showing comparisons between the skin friction distributions along the walls of the micro channel unit 1 according to the present embodiment having the optimally-designed shape and those of the conventional micro channel unit 100 shown in FIG. 8. Here, C_f and s denote the skin friction coefficient that means the skin friction force per unit area and the arc length along the wall. FIGS. 6A and 6B show the skin friction distributions on the wall within a micro channel, the connecting channel portion being curved at an angle of 90 and 180 degrees, respectively, for a Reynolds number of 1.

Skin friction distributions along the inner wall of the conventional micro channel unit 100 are indicated by dot-dashed lines, and skin friction distributions along the outer wall of the channel unit 100 are indicated by dot-dot-dashed lines. Skin friction distributions along the inner wall of the optimally-shaped micro channel unit 1 according to the present embodiment are indicated by solid lines, and skin friction distributions along the outer wall of the channel unit 1 are indicated by hidden lines.

Referring to FIG. 6A, the skin friction that is maintained constant when fluid flows in the straight channels varies when the arc length s ranges between 3 and 4.2 in the curved connecting channels. In the conventional micro channel unit 100, the skin friction increases on the inner wall of the connecting channel portion 120 and decreases on the outer wall of the connecting channel portion 120 due to the curvature effect of the shape.

In contrast, in the case of the micro channel unit 1 according to the present embodiment, the skin friction is nearly zero on both the inner and outer walls of the connecting channel portion 20, except at the connection points of $s=3$ and 4.2, where abrupt change in the skin friction occurs. Thus, based on the fact that the amount of power required to cause the fluid to flow is proportional to the skin friction, the power in the connecting channel portion 20 is significantly reduced as compared with power in the conventional connecting channel portion 120.

Similarly, this situation occurs in the connecting channel portion 30 curved at an angle of 180 degrees as shown in FIG. 6B.

FIGS. 7A and 7B are graphs showing pressure distributions as the fluid moves through 90- and 180-degree curved micro channels, respectively, where C_p denotes the pressure coefficient on the wall.

While pressure distributions along the inner wall of the conventional micro channel unit 100 are indicated by dot-dot-dashed lines, and pressure distributions along the inner wall of the channel unit 1 according to the present embodiment are indicated by solid lines. The pressure distributions along the outer walls are almost the same as the pressure distributions along the inner walls, so no indication has been made on the graphs.

It can be observed in FIGS. 7A and 7B that in the conventional micro channel unit, the pressure decreases almost linearly along the walls of the straight and curved channels. In contrast, in the case of the channel of the present embodiment,

the pressure linearly decreases in the straight channels but remains nearly constant in the curved region wherein $3 \leq s \leq 4.2$ in the 90-degree curved channel (FIG. 7A), and wherein $3 \leq s \leq 5.2$ in the 180-degree curved channel, respectively (FIG. 7B), except at the connection points, where sharp change in the pressure occurs. That is, the pressure differences between both ends of the connecting channel portions 20 and 30 according to the present embodiment is significantly reduced compared with the conventional connecting channel portion by about 10 - 20 %.

As is evident from FIGS. 7A and 7B, there is little fluid pressure loss in the connecting channel portions 20 and 30 according to the present invention, which means that the amount of power for driving the fluid flow is significantly reduced.

The connecting channel portions 20 and 30 are designed to have an optimal shape using the optimal control theory. Thus, a pressure drop that may occur at either end of the connecting channel portion can be significantly reduced by adopting similar shapes of connecting channel portions compared with the conventional connecting portions 120 and 130 having the same width as those of the straight portions 110, although they do not achieve the same effect as the connecting channel portions 20 and 30 in the present embodiment.

While this invention has been particularly shown and described with reference to a micro channel unit used in a biochip, it should not be construed as being limited to this embodiment. That is, this invention is applicable to various other fields where micro channel units are used.

As described above, a micro channel unit according to the present invention designed so that the connecting channel portion is wider than the straight channel portion can reduce the pressure drop when fluid passes through the connecting channel portion, thereby reducing the amount of power required to drive the fluid.